

Noise Attenuation

At the end of this Session, you will be able to:

- **Define the term 'signal'.**
- **Define the term 'noise'.**
- **Define the term 'signal to noise ratio'.**
- **Define the term 'coherent noise'.**
- **List at least 3 types of coherent noise.**
- **Define the term 'random noise'.**
- **List at least 3 types of random noise.**
- **List and describe/show at least 8 types of noise that can be found on a marine shot record.**
- **List and describe/show at least 8 types of noise that can be found on a land shot record.**

At the end of this Session, you will be able to:

- **Define the term 'spike'**
- **Describe at least 2 problems that spikes may cause during processing.**
- **List at least six noise attenuation techniques.**
- **Describe how you would attenuate noise based on its frequency content, dip, velocity or amplitude level.**
- **Define the terms 'muting', 'first break mute', 'inner trace mute' and 'surgical mute'.**
- **Describe how first break muting, near trace muting and surgical muting can be used as a noise attenuation process.**

At the end of this Session, you will be able to:

- **Define the term ‘Multichannel filter’ and ‘FK filter’ as used during data processing.**
- **Define each of the following terms as used in XT domain processing: positive dip, negative dip.**
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- **Produce a diagram that shows how each of the following events in the XT domain are represented on an FK spectrum: shallow dip, steep dip, flat event.**
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- **Describe how specification of taper zone during FK filter definition can affect the quality of the filter design.**

Signal Processing

Energy within a seismic trace consists of -

Signal:

that carries desired information

Noise:

**that contains unwanted
information**

Signal Processing

Aim of signal processing is to enhance signal and reduce noise, that is

Increase Signal to Noise (S/N) Ratio

where S/N ratio may be defined as

$$\frac{\text{energy (or amplitude) of signal}}{\text{energy (or amplitude) of noise}}$$

Sometimes denominator may be total energy i.e. S + N

Random Noise

- energy which does not exhibit correlation from trace to trace
- not generally source generated (the noise would be present whether we were shooting or not)

Examples:

Swell Noise

Instrument Noise

Shark bites

Powerline Noise

Traffic (vehicles, people, animals)

Wind

Falling Debris

Earthquakes

Coherent Noise

- predictable from trace to trace across a group of traces i.e. have a phase relationship between adjacent traces
- often source generated (if we weren't shooting the noise would disappear)

Multiples
Direct arrivals
Ground roll
Refractions
Airwave
Cable Jerk
Autofire
Ship's propeller

noise

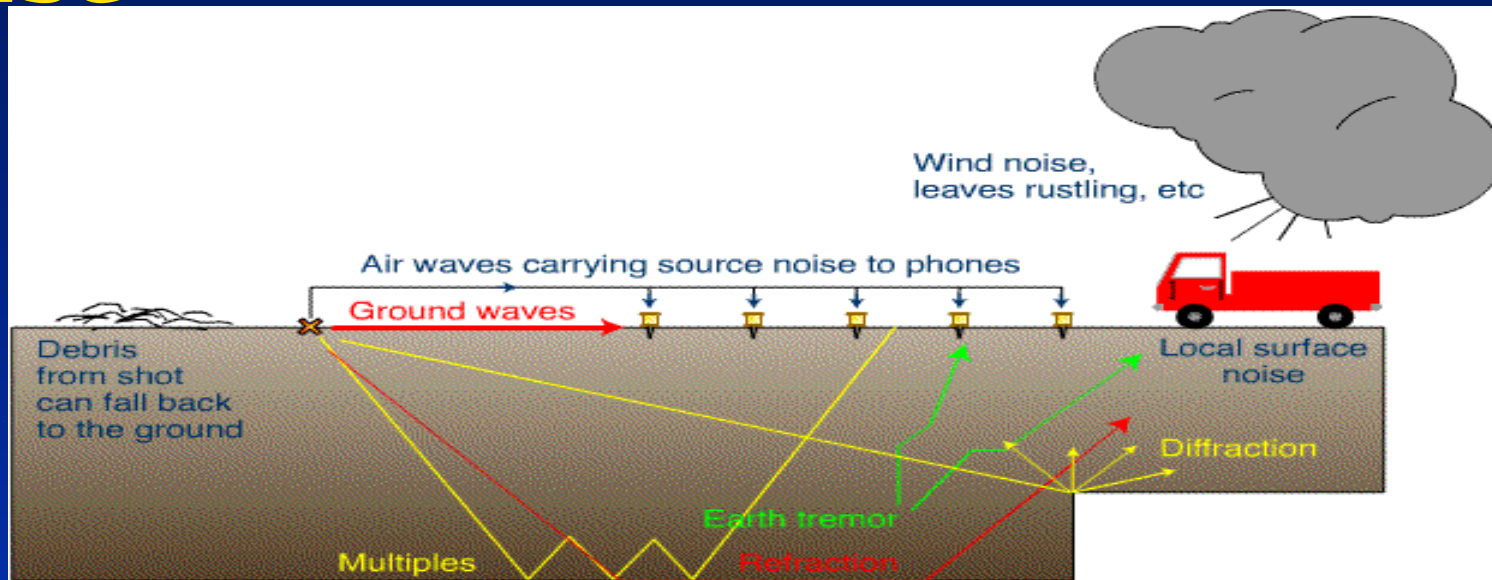
Other Noise

- In the last 2 slides we have said random noise is not generally source generated and coherent noise is often source generated
- So when is random noise source generated?
Falling debris from a dynamite source (though source generated we cannot predict if it will occur or not)
- And when is coherent noise not source generated?

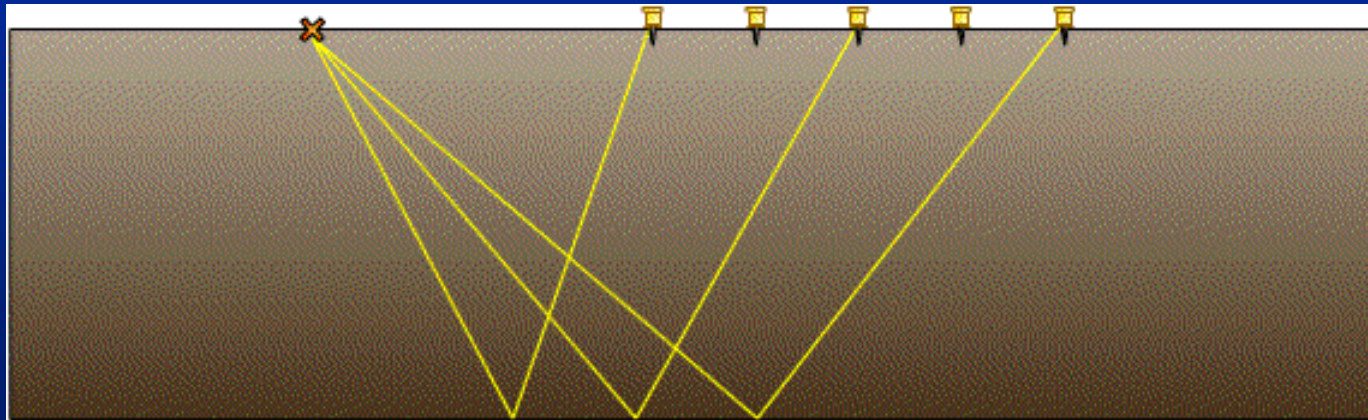
Rig Noise (though not source generated is said to be coherent because its predictable from trace to trace, and is always the same)

Another Ship (this is said to be randomly coherent or coherently random)

Noise



When all we wanted was



NOISE ANALYSIS - MARINE

noise / data problem	random/coherent
Autofire	Coherent
Direct arrivals / water borne energy	Coherent
	Random
Spiky traces	Random
Swell noise	Coherent
Ships propeller noise	Coherent
Cable jerk	Random
Shark bites	Random
Deep random / ambient noise	Coherent
Multiples	Random

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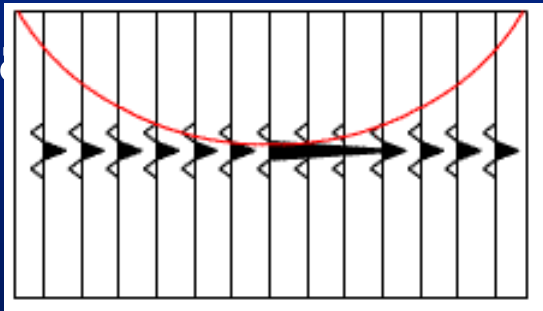
Spikes

A spike has a white frequency spectrum, that is it contains all frequencies.

Its Random, high amplitude and short lived in time.

They are generally caused by some kind of electrical or electronic blip within the recording system

- Affects amplitude scaling processors severely
- Produces impulse response of any filter applied
- ‘Noise’ (impulse response) spread to adjacent channels/ traces by multi-channel processors e.g. F-K, DMO, migration (‘smiles’!) etc



How to remove noise

Firstly we need to identify an attribute of the noise that separates it from our signal.

For example if our noise is low frequency and our signal is high frequency

The main attributes of seismic data are

Frequency

Amplitude

Velocity

Dip

Two way Travel Time

Frequency

**low-cut, high-cut, notch
frequency filters**

**Lots of noise can be distinguished by it
frequency content.**

**Low frequency noises include swell noise,
ground roll.**

High frequency noises include airwave.

**Powerline noise will have a specific frequency
value which we can remove using a notch
filter.**

Amplitude

Despike, Deband, RNA,

Denoise

Most of the above sfm's work in the following way.

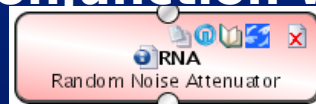
A threshold parameter is decided upon. The amplitude of the data is then analyzed over time windows. If the amplitude of the data in the time window is greater than the specified threshold, the data within the analysis window is considered to be noise. Care must be taken to choose thresholds high enough to identify noise bands while allowing trace segments with good signal to pass. There is usually an option to replace high amplitudes with zero values or to reduce the amplitude to some lower value.

Despike used to remove spikes from the dataset



Deband
conjunction with a bpfiler

mainly used for swell noise removal in



RNA

not only analyses over a time window

Velocity / Dip

FK filter

We will go into more detail on FK filters later but for now lets just say that an FK filter discriminates against data based on its dip or velocity. The important thing to remember is that the dip we refer to here is the seismic dip in ms/tr and not true geological dip.

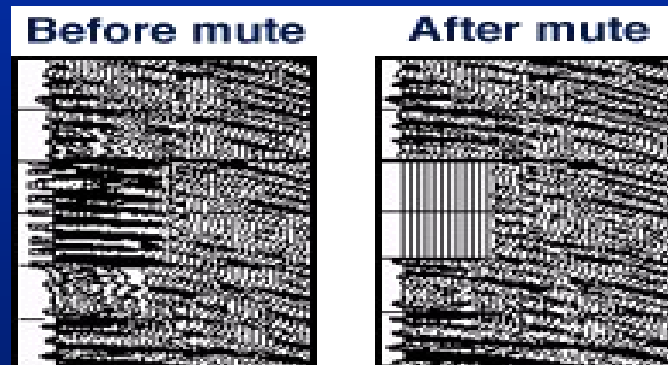
This can be used to remove noise like

Ground roll, Airwave, Multiples and Cable Jerk

Two-way Travel Time

Mute

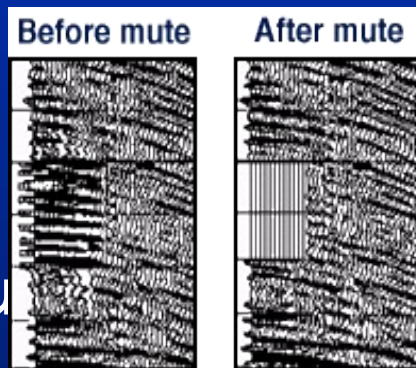
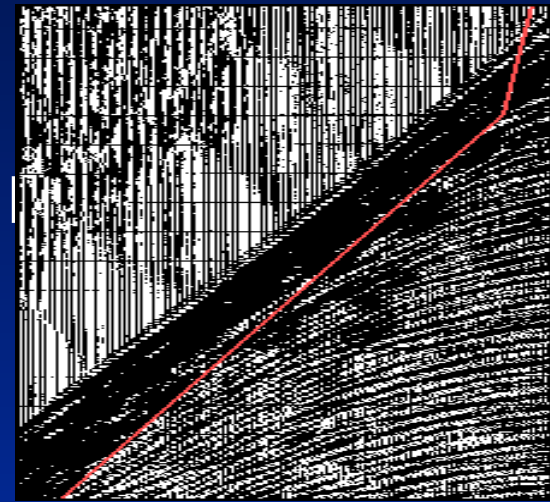
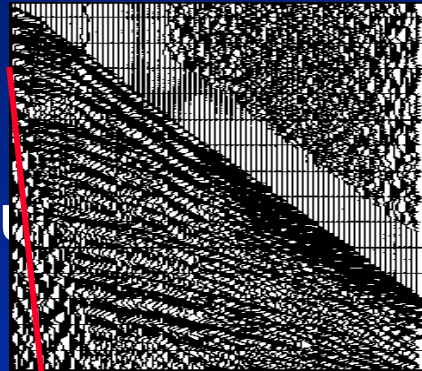
Muting is the removal or attenuation of certain parts of a seismic record or section so as to prevent that part of the data from being processed any further through the processing sequence. It basically involves zeroing amplitude values.



Types of Mute

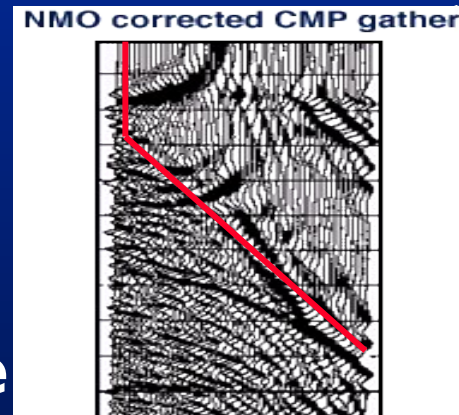
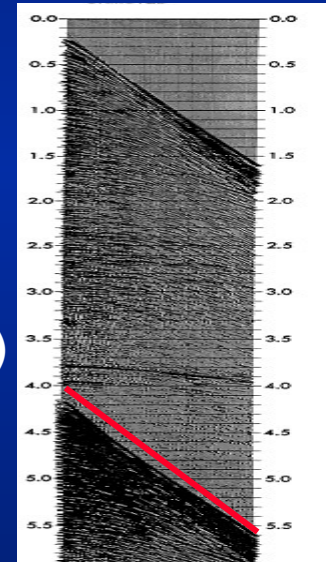
First Break / Direct Arrival Mute /

Inner Trace Mute
(multiples)



Surgical Mute
(spikes)

Tail
(autofires)



NMO Mute

Stack

A final attribute that we haven't mentioned is how similar the noise is from trace to trace. If noise appears on just one trace in a 60 fold cmp gather by the time we stack that trace with all the other traces the noises contribution to the stacked trace will be minimal.

Noise Attenuation Techniques

Random

- **Bandpass filtering**
- **Notch filtering**
- **K-filtering**
- **e.g. trace/shot summation**
- **Stacking**
- **Despike**
- **Editing (e.g. kill traces)**

Coherent

- **Bandpass filtering**
- **Velocity filtering i.e. F-K filtering**
- **Deconvolution/demultiple**
- **Muting**

NOISE ANALYSIS - MARINE

Noise / data problem	random/coherent	How to remove?
autofire	coherent	tail mute
direct arrivals / water borne energy coherent		front mute
		kill
two spiky traces	random	lowcut filter ?
noise bursts / swell noise	random	tail mute
two short traces	random	tail mute , fk filter?
cable jerk	coherent	scale by -1
two reverse polarity traces	random	stack
deep random / ambient noise	random	decon , stack , ntr mute , fk
multiples	coherent	
dead traces		kill

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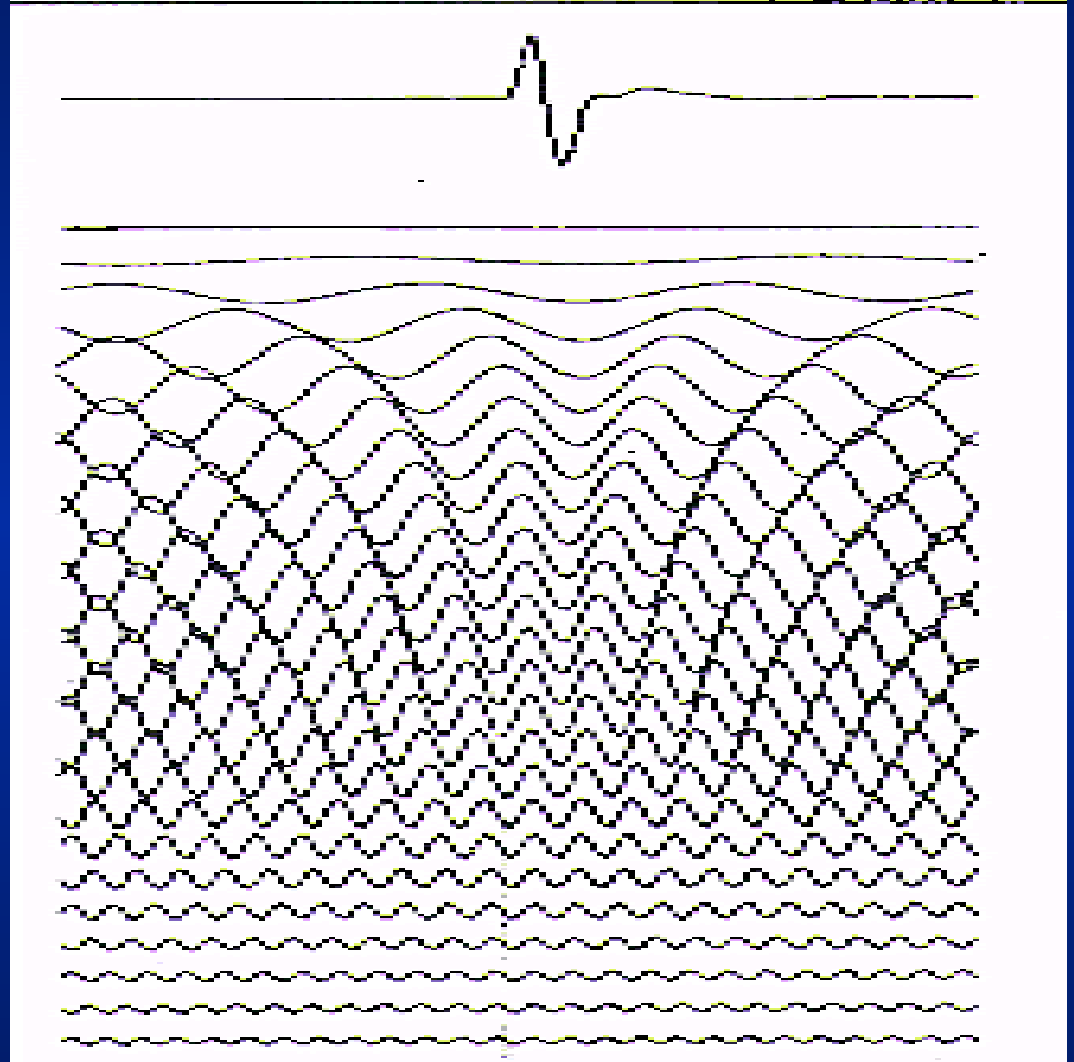
Definitions

Multichannel filter: Filtering wherein the filter characteristics are partially based on the characteristics of other channels. Basically the filter works on a number of traces at once each trace affecting the other, and not on a trace by trace basis.

FK filter: Is a dip or velocity filter. Where filtering is performed on data after it has undergone a 2D fourier transform into the FK domain.

Fourier Series

- Any repeating waveform, however complicated, may be viewed as the addition of sinusoid waves whose frequencies are integral multiples of that of the basic repetition

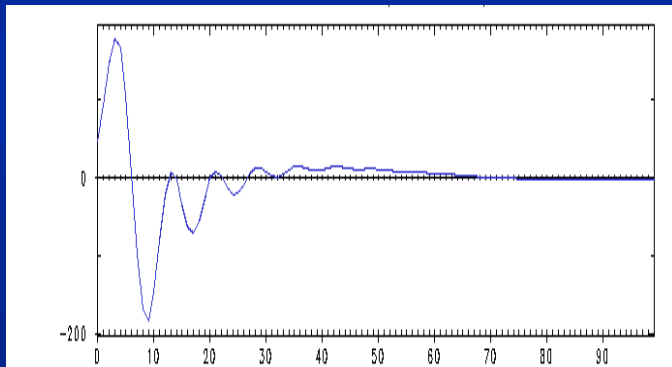


The Fourier Transform

Time domain
Domain

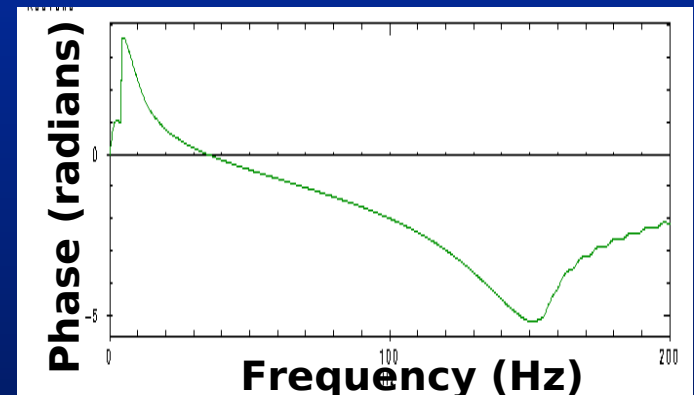
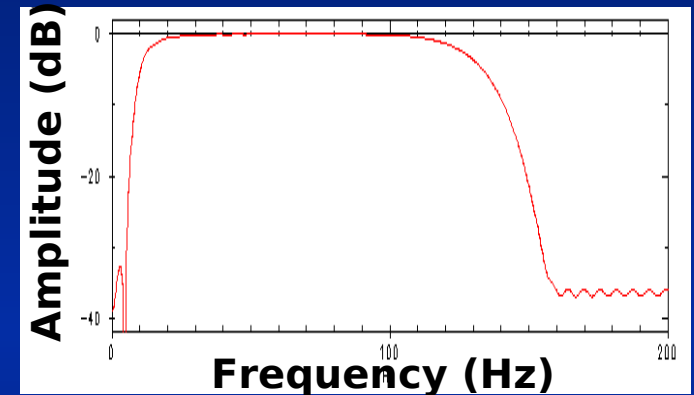


Frequency



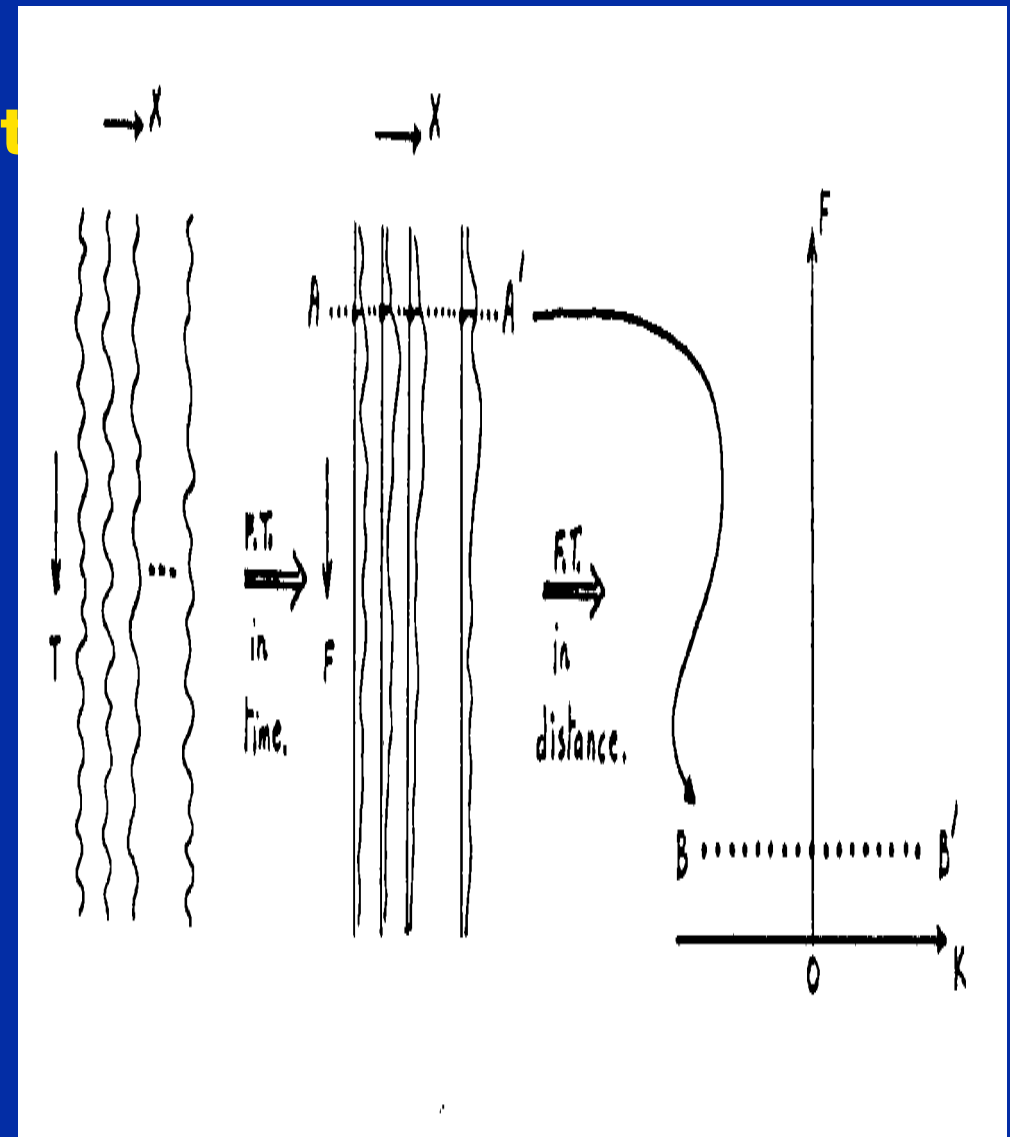
Time (ms)

1D fourier
transform



F-K Domain (2-D Fourier Transform)

- First the time-axis and its frequencies are analysed (F)
- Then the space-axis and its frequencies are analysed (K)
- Phase element is put aside and later retrieved during *inverse transformation*
- After necessary operations, an inverse Fourier transformation returns the data back to T-X domain.



Input
traces

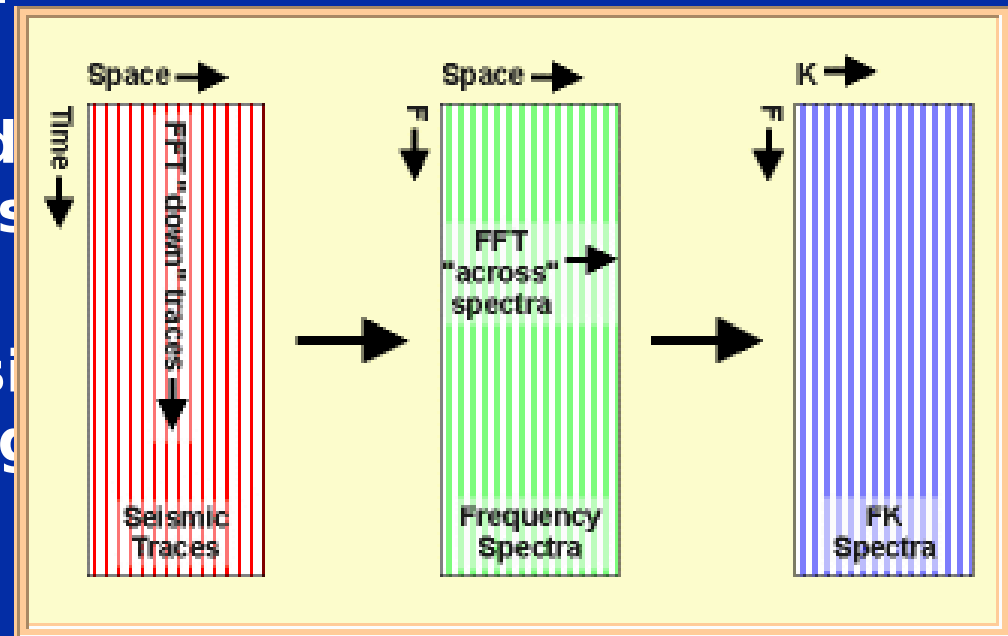
Complex
freq.
spectrum
of each trace

**2D Frequency
Domain**

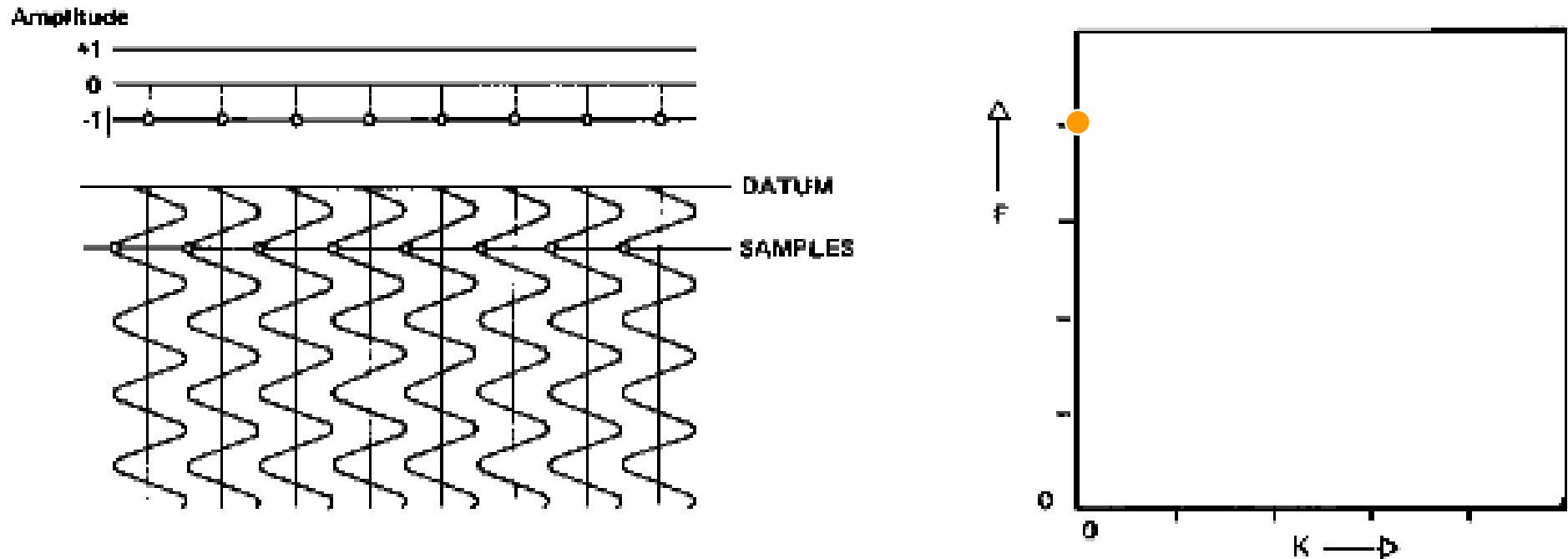


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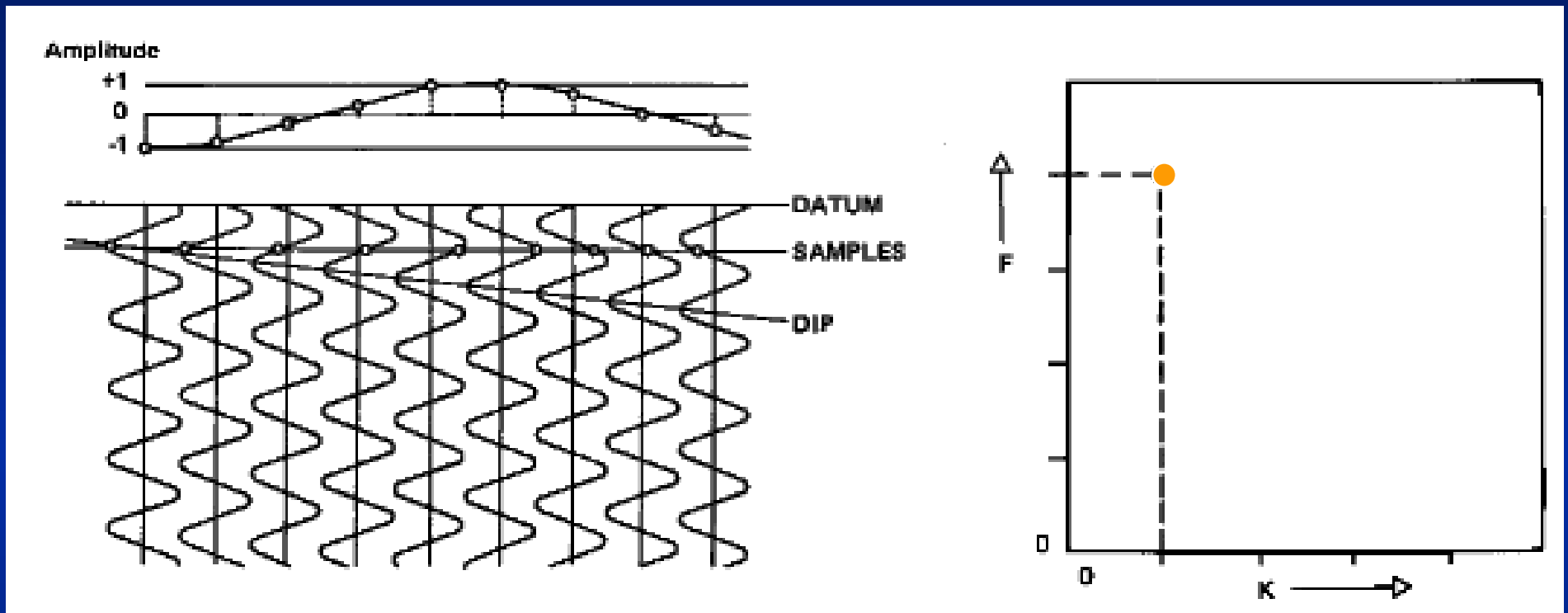
Representation of data in FK



Single frequency , zero dip.

Zero wavenumber since all wavefronts are in phase .

Representation of data in FK

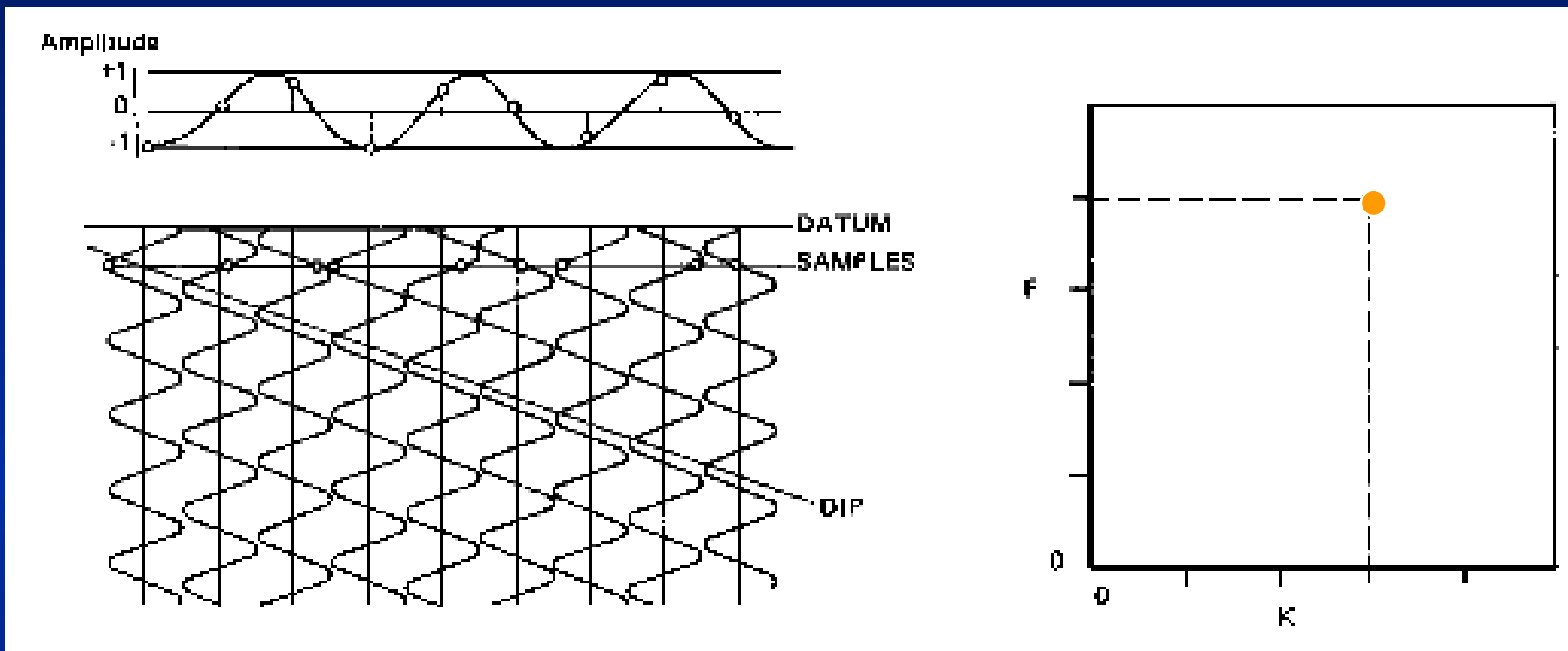


Single frequency , non-zero dip

Non-zero wavenumber since reflected wavefronts strike detectors out of phase.

Shallow dip hence low wavenumber K.

Representation of data in FK

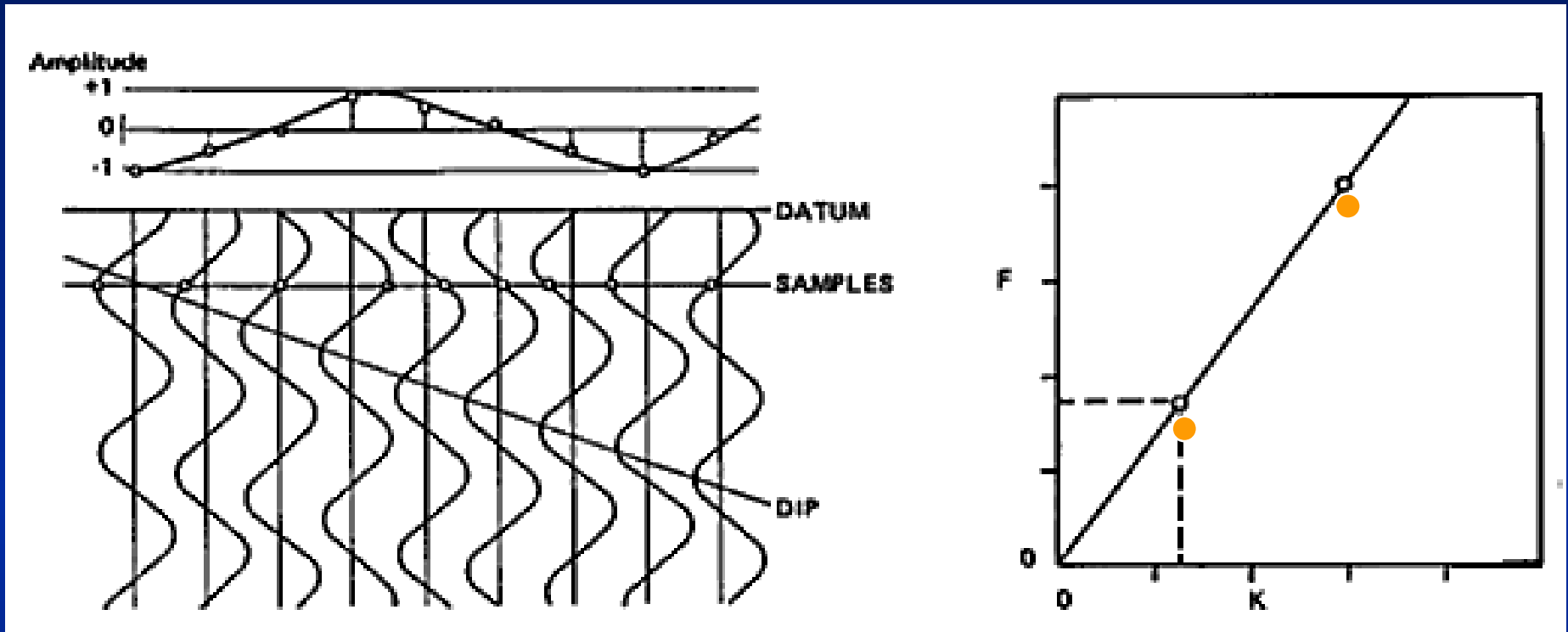


Single frequency (same as previous slide).

Higher dip hence higher wavenumber K.

Data of same frequency are separated in FK space.

Representation of data in FK



Lower frequency, same dip as previous slide

Different frequencies give different results for wavenumber from the same dip.

If we display all frequencies for a fixed dip we get a linear slope.

Know Your Events

Frequency (Hz)

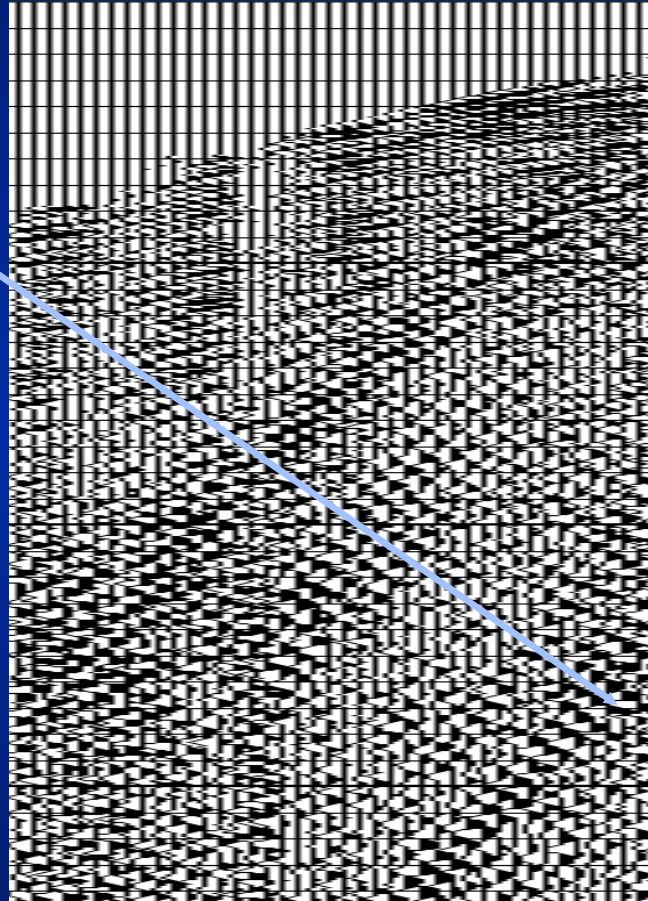
Wavenumber, K = -----
X Dip (ms / tr)

Trace Interval (m)

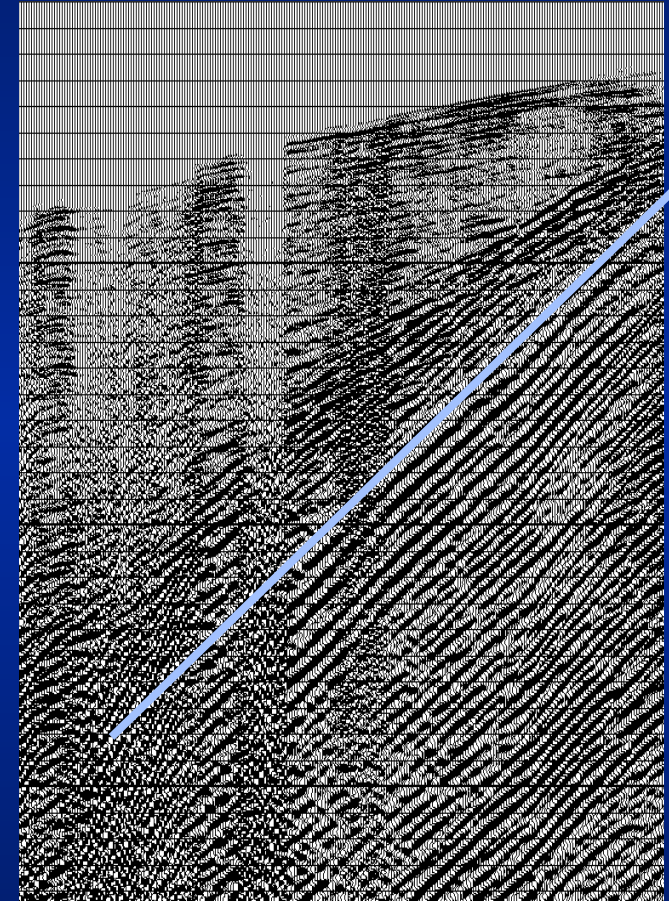
**We can now separate events on the basis of their
dips and/or frequencies**

Aliased Noise

On the left data is now aliased. This means the data appears to be dipping in the opposite direction



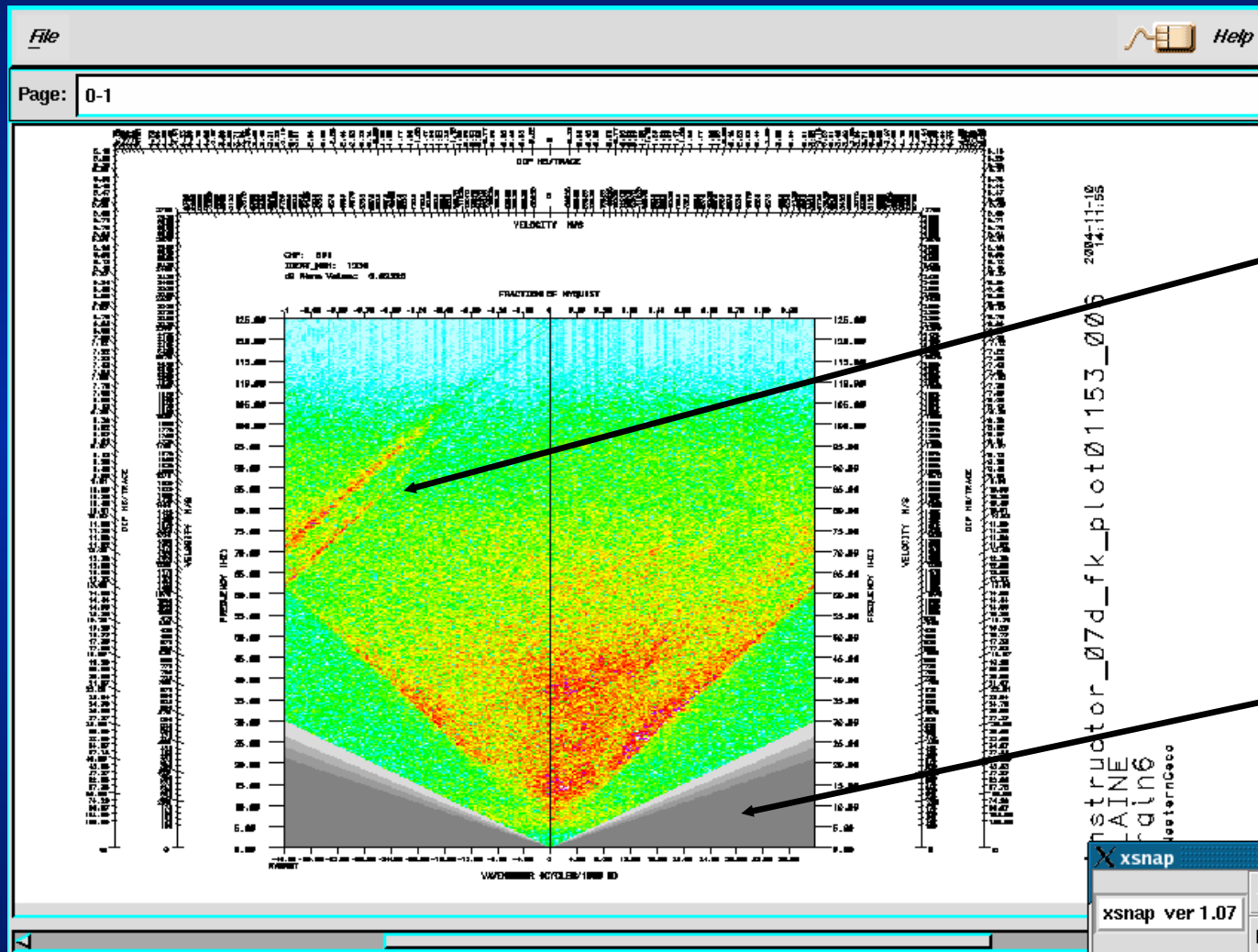
Big distance between receivers



Small distance between receivers

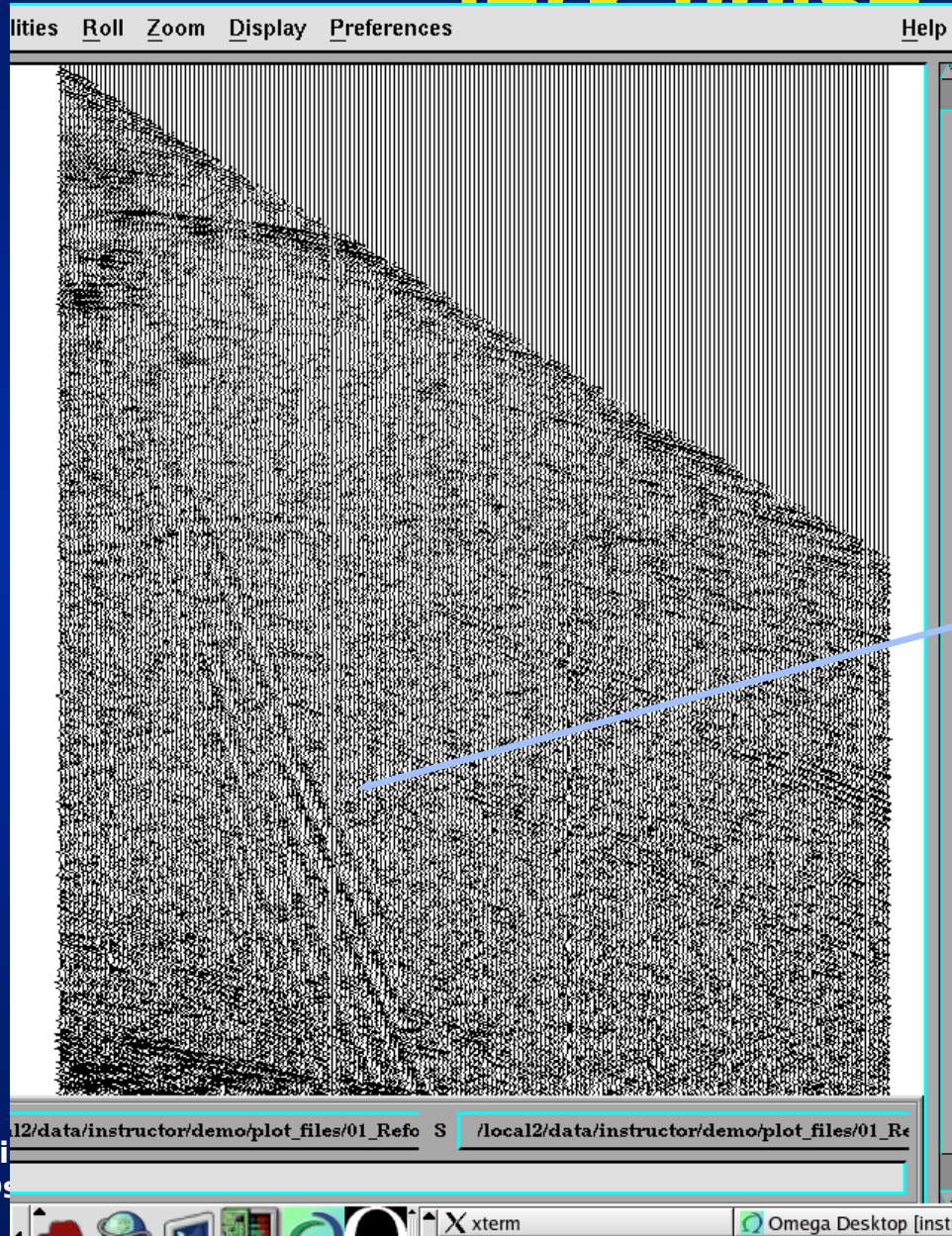
Elaine O' Brien
DP START Oslo
2004

FKPLOT of a shot record with no cable jerk noise.



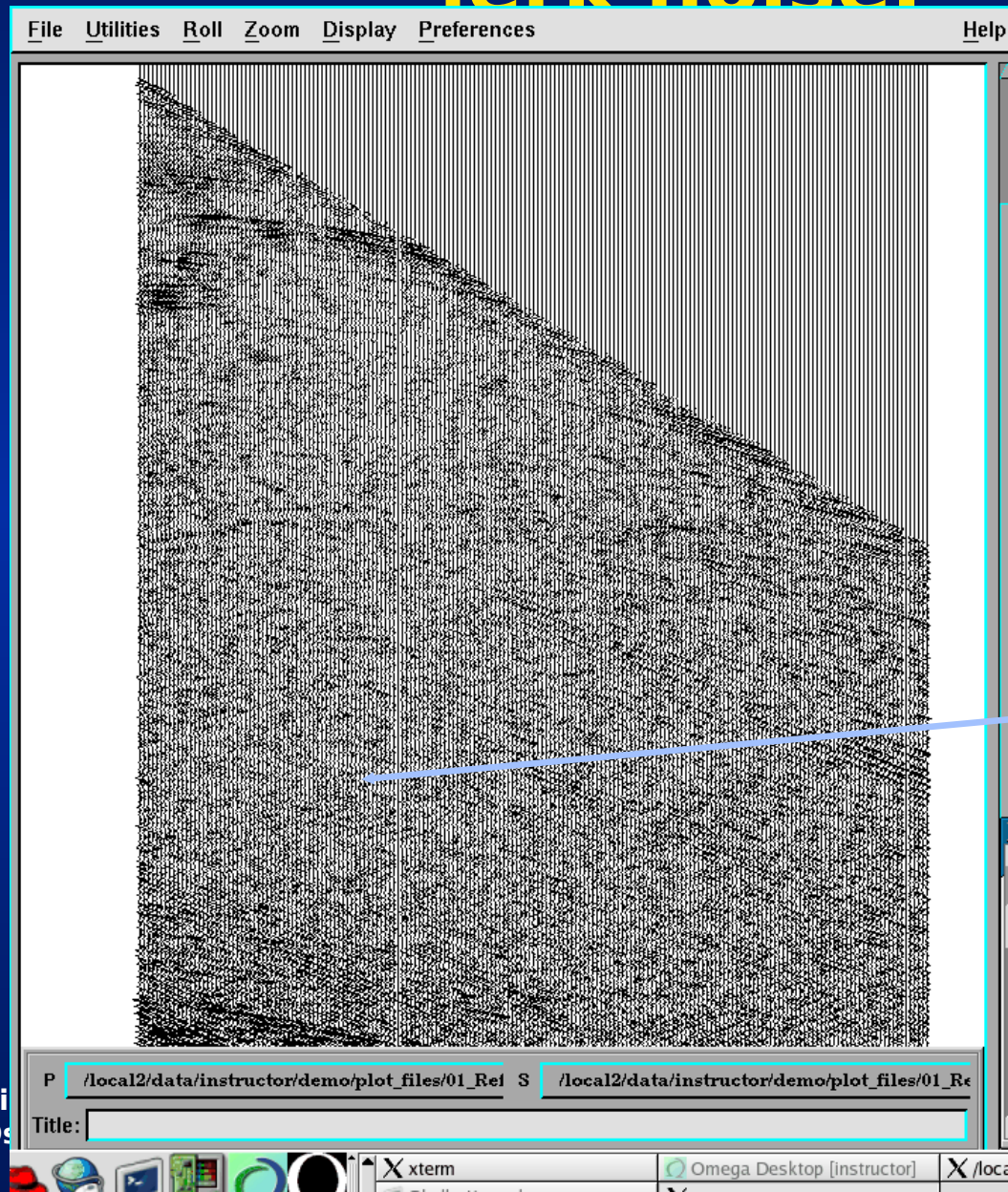
Aliased energy - could this have been avoided during acquisition? Cable jerk noise removed.

XTPLOT of a shot record with cable jerk noise



Cable jerk
noise;
steep dip
low
frequency

FKPLOT of a shot record with cable jerk noise.



Cable jerk
noise
removed

WesternGeco Sign Conventions for the Dips

In T-X Domain

Positive dip - when time increases with increasing trace position

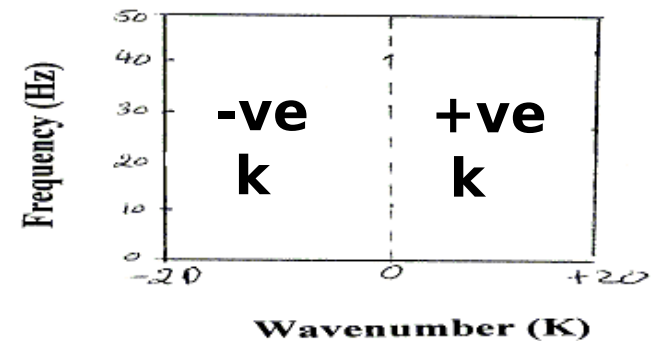
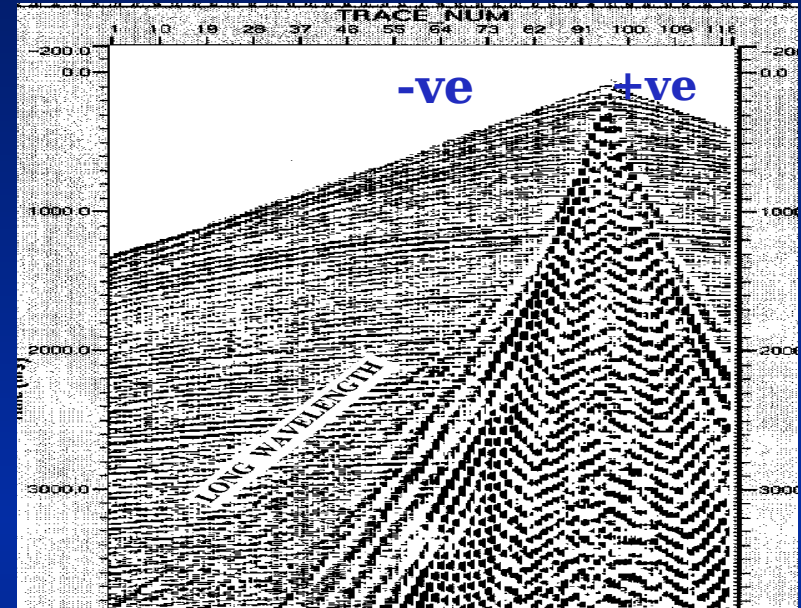
Negative dip - when time decreases with increasing trace position

In F-K Domain

Positive and negative dips in T-X domain

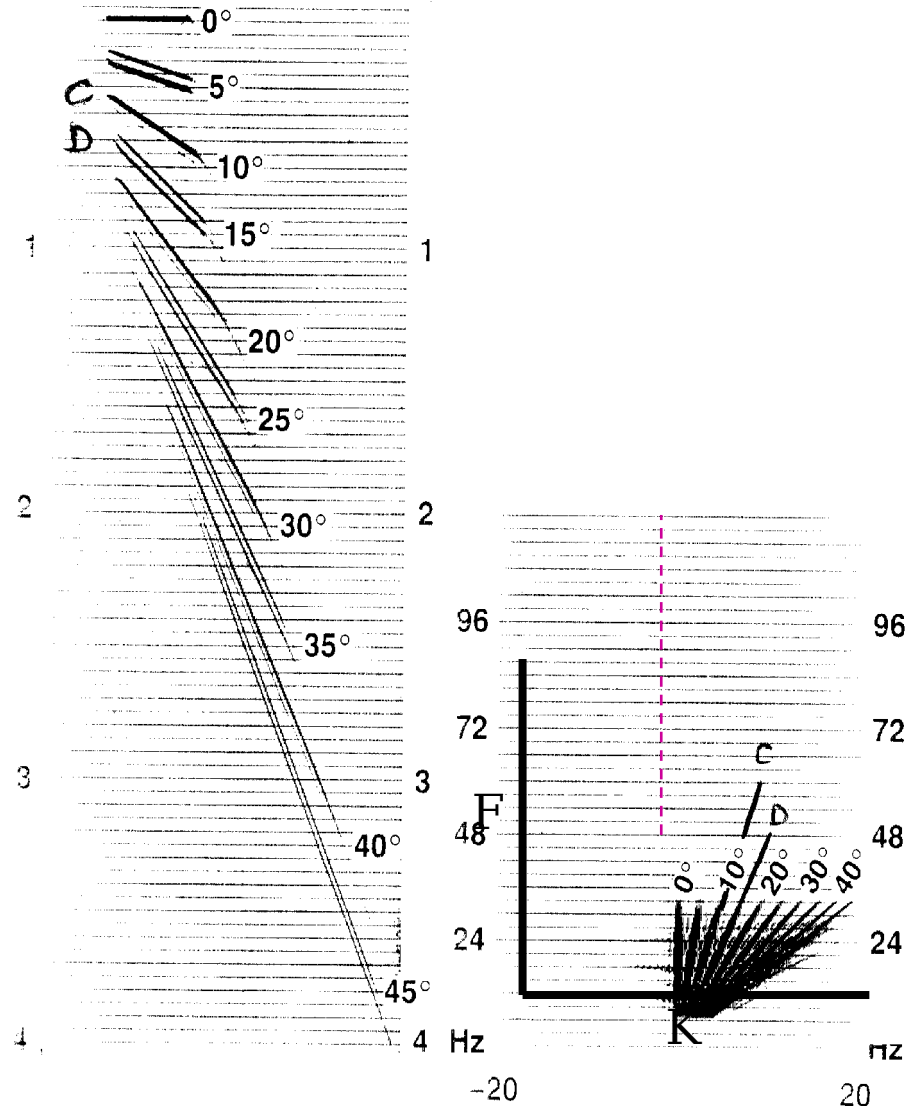
Correspond to the positive and negative

wave-number in the F-K domain



Events

- In practice, a shot record may have many events dipping differently with different frequency content
- How can we guess their whereabouts in F-K space without using equations?

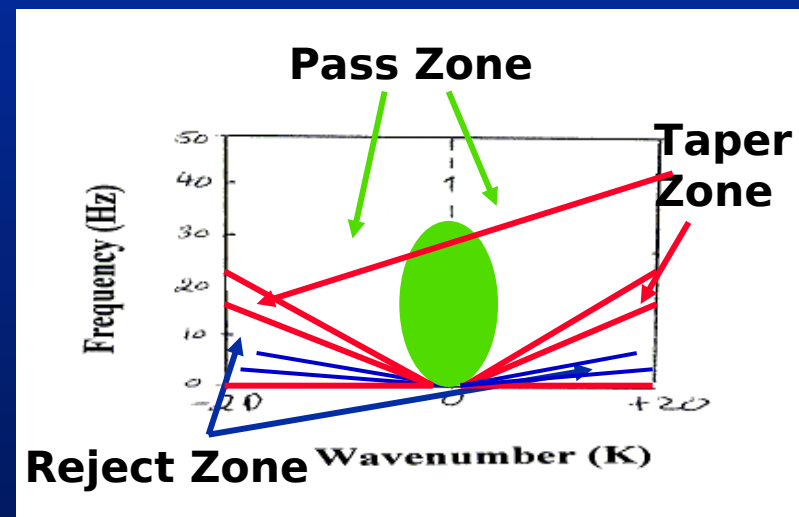
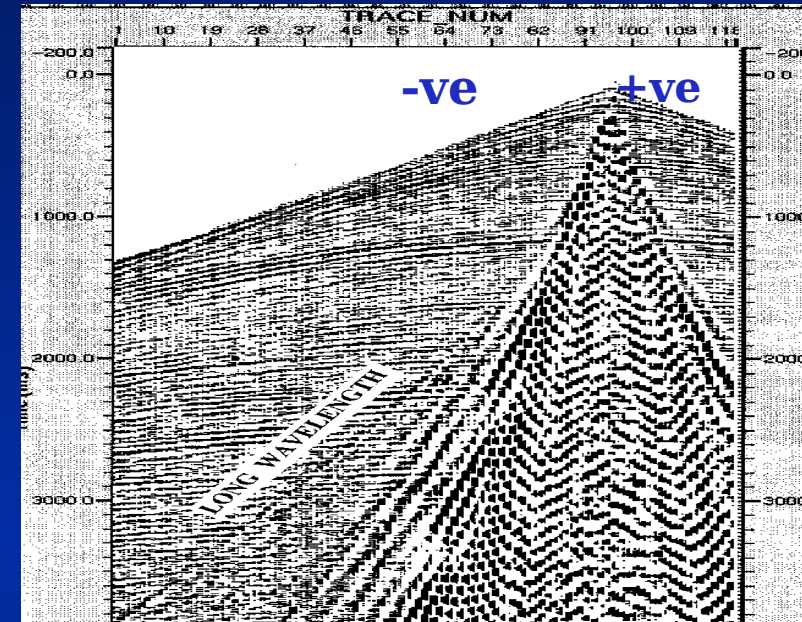


FK Filter Parameters

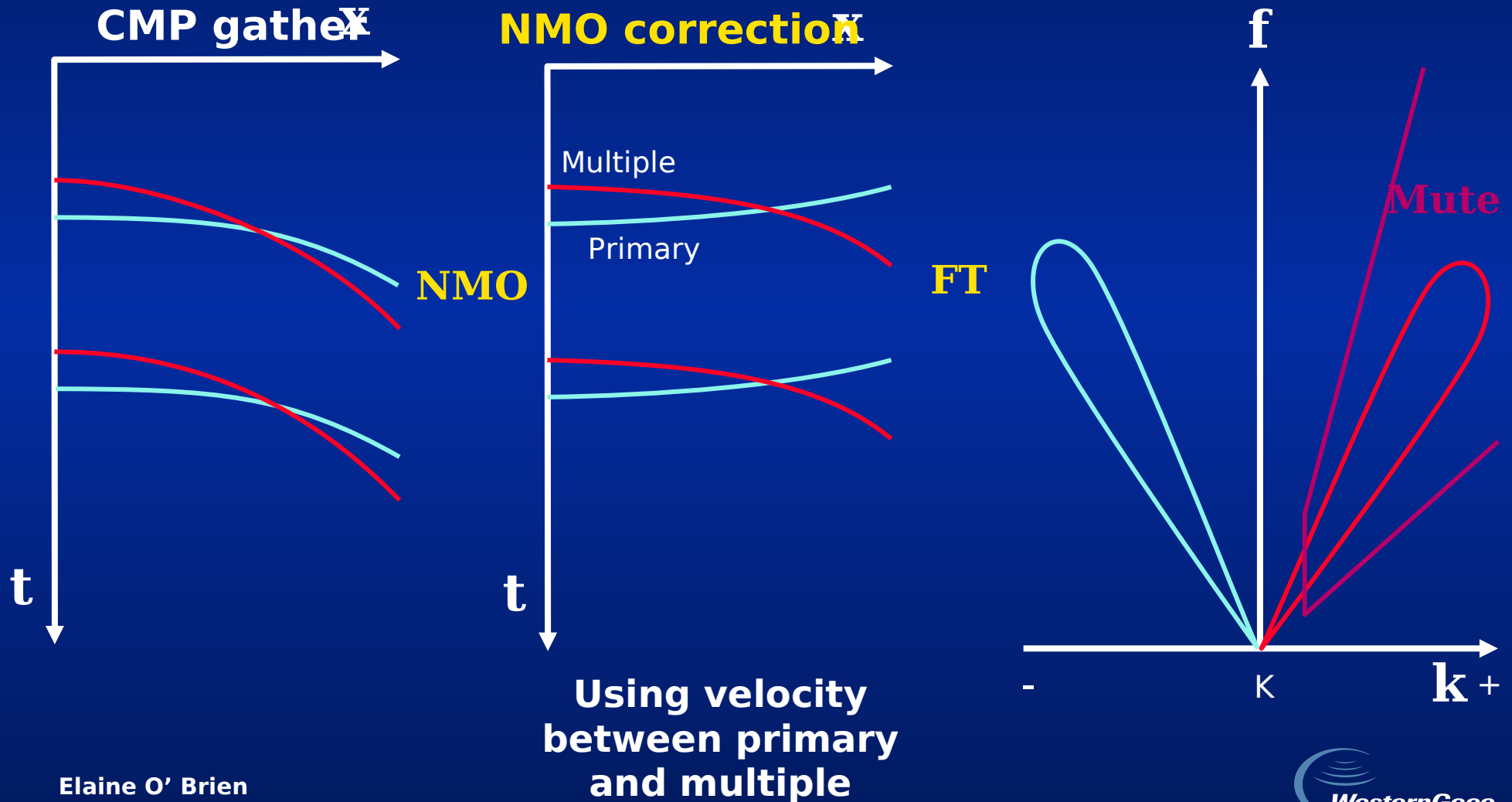
- **Pass Zone:** Allow all data within this area to pass untouched
- **Reject Zone:** Remove all data within this area. I.e zero all data within this area.
- **Taper Zone:** Gradually reduce amplitudes of data within this area. Similar to a slope on a frequency filter, the smaller the taper zone the more likely that you will get edge effects.

From the filter opposite what data will be removed from the shot record

The Ground Roll



Demultiple implemented via FK filtering



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